E/CONF.39/D/26
29 Sept. 1962
ORIGINAL : ENGLISH

UNITED NATIONS CONFERENCE
ON THE APPLICATION OF SCIENCE AND TECHNOLOGY
FOR THE BENEFIT OF THE LESS DEVELOPED AREAS

Agenda Item: D.3.4

Canada

THE USE OF RADIOISOTOPES AND SPECIAL INSTRUMENTATION FOR PROCESS CONTROL AND DEVELOPMENT IN THE MINERAL AND METAL INDUSTRIES

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THE USE OF RADIOISOTOPES AND SPECIAL INSTRUMENTATION FOR PROCESS CONTROL AND DEVELOPMENT IN THE MINERAL AND METAL INDUSTRIES

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INTRODUCTION

1. The present climate of international cooperation and technical aid extended to many of the less-developed areas provides them with an opportunity to benefit from the experience gained and advances made in other countries to obtain the highest possible productive efficiency. The extent to which electronic and radioactive instrumentation can be employed in the mineral and metallurgical industries depends greatly on the level of operations. The opening up of the mineral resources of less-developed areas can be broken down into the usual three phases through which any industrial development must pass: exploration, process development, and routine processing. To these should perhaps be added long-term research as a fourth phase usually associated only with more advanced technologies. Each of these phases has its own specialized requirements for equipment, some of which depend heavily on the available personnel and their relevant skills. It is this interplay of improved process efficiency by semi-automatic controls and its requirements for skilled personnel that will be discussed here as it applies to resources development in underdeveloped areas.

2. In the three development phases mentioned, there is a steady increase in complexity in equipment requirements as one passes from exploration to routine processing. Opposed to this, there is a reverse process of dilution in the average level of skill and specialized knowledge required as the scope of operations grows.

3. The exploration phase usually requires a highly knowledgeable person directing a team capable of using a range of instruments and techniques under constantly varying conditions. These techniques include various methods of aerial surveying, ground prospecting and borehole logging, supported by geochemical and mineralogical analyses. The less-developed areas may well depend on technical aid from more advanced countries to press ahead in this field for many years to come.

4. The process development phase involves small-scale mill tests, beaker-scale laboratory extraction work and, finally, pilot plant operations. All these operations require an experienced staff and well-equipped laboratories. Much of the equipment must be properly instrumented to provide all necessary data on process variables and laboratory results, such as analytical determinations, feed densities, flow rates, pH values, gas pressures and many others. Instruments for such measurements have been available commercially for many years and it should not pose too big a problem to train operators to collect and record instrument readings. The actual direction of development tests must always devolve on a trained professional with considerable theoretical and practical experience, who in many cases may have to devote a fair share of his time to training his operating staff.

5. The routine processing or mill operating phase will in general depend to the greatest extent on local resources. The design of the plant must take into account both economic and labour problems in addition to the usual requirements for a high degree of plant efficiency and reliability. In the mineral and metal industries this often implies that an early decision has to be made whether to adopt more modern, semi-automatic means of process control and operation, or whether to retain a more traditional approach involving a great number of relatively unskilled workers performing routine operations as well as their training and capabilities permit.

6. It has often been argued that in many underdeveloped areas unskilled manpower is the chief readily available resource and that the latter approach is more suitable, particularly since skilled technicians may be scarce and breakdowns of expensive control equipment may be hard to remedy due to lack of spares and of experienced repair men. However plausible such an argument may appear, particularly as a means of ensuring wider employment of unskilled labour, it suffers from a number of obvious contradictions under present-day conditions.

7. One is the inherent waste of valuable resources in mining and metallurgical operations conducted without proper control of process variables. Experience in Canada and in many other countries has shown that spectacular improvements can often be made in the yield and overall production of extraction plants when important chemical or physical factors are properly controlled; this in most cases leads to a substantial lowering of costs of production. Many of these factors cannot be judged by the operator by experience alone, but require instead the use of properly designed, often highly specialized, process instrumentation.

8. The second weakness in the argument for the use of large numbers of unskilled labour is its inherent inefficiency. In those countries where this approach has been practised widely, it has been found that almost invariably the labour force suffered from excessive turnover. This required a large proportion of the work force to be tied up in training courses, lasting from a few days to several weeks in some cases, and an often longer period of adjustment and learning on the job, with a low level of average efficiency and relatively high cost of production per man.

9. This practice contrasts with a semi-automatic plant installation operated by a smaller number of more highly trained men who are less likely to find competitive posts elsewhere at similar remuneration. By careful selection, a sufficient number of men can be chosen to attend training classes similar to those given by several North American instrumentation companies to acquaint technicians thoroughly with the operation and maintenance of selected electronic equipment. Such courses may last two to three weeks and do not demand any theoretical knowledge of the process being controlled or of circuit theory as such. Extension of such schemes to many of the less-developed countries, together with mechanical and electrical design to suit the climatic conditions of the area, would go a long way to ensure efficient and economic operation of plants.

10. It is an obvious corollary that probably more care has to be given than hitherto to engineering design of process instrumentation intended for use in less-developed areas, where often very adverse climatic conditions and uncertain electrical power supply conditions will be encountered. To minimize repair problems, more equipment should

be designed in modular sub-assemblies so that defective sub-units can be readily replaced by spare units of easy accessibility and moderate cost. This is achieved to an increasing extent by means of printed circuit techniques and transistor circuits. Such an approach to servicing is likely to overcome the common tube replacement problem and may be more adaptable to regions with difficult communications.

11. Another vital matter, which can only be mentioned in passing, is the need for detailed instruction manuals with complete circuit and layout diagrams, and careful operating and trouble-shooting instructions in the language of the prospective user. This may well prove to be a major problem to the average instrument supplier and may deserve some special government attention and support.

THE USE OF RADIOACTIVE SOURCES IN CONTROL EQUIPMENT

12. Radioactive materials are used to an increasing extent in the metallurgical industry. Because of their relative novelty and the special legislation covering their use in most countries, many potential users still feel mildly uneasy when the use of radioactive materials is suggested in routine operations. For a sensible discussion it is essential to classify such uses according to whether the radioactive material is enclosed or sealed permanently, or whether it is dissolved or entrained in other substances, and according to its mounting, either in a fixed location or in a mobile installation.

13. Mobile, sealed radioactive sources are used primarily in exploration work and for radiographic inspection. Typical applications include gamma-ray and neutron borehole logging[1, 2], gamma-activation analysis of beryllium[3, 4], and other neutron sources for mine analyses[5]. The need for mobility limits the amount of shielding that can conveniently be carried, although truck installations containing several curies of activity have been used. Needless to say, careful handling in accordance with instructions is required to avoid overexposure of the operator or any other bystanders.

14. Similar considerations apply to the use of fixed, sealed sources in control equipment. While the question of the usefulness and desirability of reactor construction in underdeveloped areas is still a contentious subject, there can be no question as to the usefulness and economic advantage of utilizing radioactive sources in certain industrial applications.

A properly shielded radiation source, installed in flow or density gauges, in itself presents no problem of handling or maintenance; only its associated electronic detector and control circuits will require periodic inspection and maintenance, like any other electronic gear. In general, no great difficulty has been encountered in designing such industrial gauges in such a way that any operator is well shielded from any radiation from the radioactive source, thus avoiding the need for classifying him as an "occupationally exposed person". If the source is limited in use by the half-life of its effective nuclide, replacement for such radioactive sources can be obtained quite readily from any of the many countries now exporting radioisotopes.

15. The main advantages of radioisotope radiation sources lie in their ready availability, relatively low cost, absence of moving parts or high-voltage circuits (which might require frequent maintenance), silent operation, and simplicity of installation. The latter point becomes evident when one compares the installation of a radioactive density gauge or level indicator outside the pipe or vessel containing the medium being controlled with any alternative non-radioactive method. All these advantages matter when maintenance and staff training considerations are paramount. By choosing a radioisotope of the appropriate character as to type of radiation and energy emitted, suitable conditions can be established to meet a wide variety of requirements[6]. Most of the gauging systems in industrial use utilize changes in the intensity of radiation transmitted or backscattered from the medium under observation. This radiation level is detected by means of a Geiger counter, scintillation counter or ionization chamber, integrated, and then fed to a conventional electronic recorder or controller.

16. Industrial uses of sealed sources can be classified as follows:

a) High-level radiation sources for purposes of sterilization, pasteurization and food preservation, as well as a processing technique in the plastics industry[7], and the petroleum industry[8];
b) Static eliminators and similar ionizing devices;
c) Thickness gauges, density gauges and level indicators;
d) Markers and indicators, such as are used for emergency lighting and labels or for the identification of selected materials;
e) Flow meters and radioactively tagged "go-devils" in pipe lines[9].

17. Of these, only the third and last groups qualify as standard process control equipment in the sense that they can be obtained commercially and may be part of an overall program of plant control and process supervision. Among these applications the use of radioactive sources in thickness and density gauges for slurries, solutions, metal foil or paper by transmission or backscattering methods have received the greatest attention[10,11,12], but many other applications are constantly being introduced. Similarly, a wide range of level gauges are in use to control liquid levels in leach tanks and oil refineries[13], scrap metal feed in blast furnaces[14], and coal or coke levels in fuel hoppers.

THE USE OF RADIOACTIVE TRACERS IN METALLURGY

18. The use of radioactive tracers, i.e., essentially unsealed, dispersed radioactive materials, calls for a different philosophy and more careful handling precautions. Tracer methods are most useful in development work and for occasional checks of proper operating conditions in routine process work. Their use in continuous process operations is rarely feasible, both for reasons of cost and the limitation in supply, and because of difficulties in supervision and waste disposal under such conditions.

19. There are many potential uses of tracers in the development of chemical processes, the development of mill circuits in extractive processes, and in pyrometallurgy. Typical uses included measurements of flow-patterns in leach plants[15], of contact and residence times in kilns and furnaces[16], of leak detection in pipe lines[17], and of flow problems in hydrology and mining[18]. Although the technique of applying radioisotopes in such tracer tests is not difficult, they should be conducted by a properly qualified scientist or engineer to guard against unexpected exposures and serious contamination. However, the usefulness of tracer methods in the metallurgical field is so great, and the light they can shed on actual plant operations so useful, that one can only hope that a steadily increasing number of scientists from less-developed countries will be able to receive training in this field.

20. A few examples only can be given here of tracer applications in extractive metallurgy and related fields. By adding a suitable tracer it has been found possible to check flow conditions in leach tanks and flotations cells, and to remedy undesirable short-circuit conditions. Similarly, in kiln operations adsorption of a tracer solution on a feed sample can indicate residence times of different feed components, segregation effects, furnace brick wear, pile up and possible short-circuiting of finer fractions. In mines, radioactive tracers provide a better means than fluorescent tracers to tag mine waters and to investigate leakage or contamination problems.

21. In all these cases, careful analysis of the problem can lead to safe use and ultimate disposal of radioactive materials. However, it is not recommended that unsealed radioactive materials be used in any continuous application where the total quantity used may be excessive and ultimate recovery of the active material impractical or impossible. The "post-activation" of non-active tracers may be a possible answer to these problems.

ELECTRONIC EQUIPMENT AND PLANT CONTROL

22. All these radioactive uses as well as other control applications depend on the development of reliable and relatively simple electronic circuits. By using transistors to the fullest possible extent, maintenance problems and down-time can be greatly reduced and the problem of replacement parts can be minimized.

23. There have been many developments of control equipment for mills and extraction plants in recent years and it may be useful to mention a few here that have been developed in Canada. Equipment is now available to control automatically the load of grinding mills, the conductivity of leach solutions of metalliferous ores, the oxygen content of cyanide solutions in gold extraction, or the iron content of iron ore concentrates. Considerable effort has been devoted to improve process control in the extraction of uranium. Automatic picker units have been devised to remove non-radioactive gangue from mine ore; methods for the rapid assay of ore and automatic control of effluent solutions have also been introduced. Many of the lessons learned in the uranium industry are now being applied to other branches of the mining and metallurgical industries. This is particularly relevant to some of the older industries like coal mining, gold mines, iron mines and steel plants. In all of them there is a gradual awareness of the benefits that can accrue from a detailed knowledge of the plant process and the direct control of plant conditions. Most of the instrumentation involved has been used in the laboratory for many years, but it is only in the more modern plants that routine records are kept continuously of such variables as pH, moisture, density, temperature, porosity, gas content, conductivity or pressure.

24. As the more mechanically-minded among the metallurgists are converted to accepting such electronic instruments as commonplace in the beneficiation and refining of metalliferous ores and other minerals, the level and value of production of such materials is bound to improve.

25. It may well be that those countries where a mineral technology is started without too many entrenched preconceptions may find it easier to proceed to optimum conditions of semi-automatic process control. The less-developed countries are fortunate that much of this control technology is available for their use and can be readily adapted to their needs. By grasping these opportunities they will help to develop their own mineral resources and to utilize them as effectively and economically as possible.

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